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I wanted to share with you the final report completed by NAU and funded through NLCS Research Support Program. Thanks to the continued efforts of Kevin Miller for signing this project through completion.

The report title is "Toward an integration of historical and contemporary data to inform assessment, monitoring, and decision-making on the Grand Staircase-Escalante National Monument" and it evaluates some of the range data collected over the years.

The report is saved here Z:\Science Program\Science 1\Research Projects\NAU AIM and attached for those not on our network.

Dana

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NORTHERN ARIZONA UNIVERSITY

Lab of Landscape Ecology and Conservation Biology

FINAL REPORT

(December 7, 2017)

For the project entitled:

Toward an integration of historical and contemporary data to inform assessment, monitoring, and decision-making on the Grand Staircase-Escalante National Monument

Submitted to:

NLCS Research Support Program

By:

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Introduction

The principal goal of the work described in this report was to evaluate the potential for integrating historical (hereafter 'legacy') and contemporary vegetation assessment and monitoring data at Grand Staircase-Escalante National Monument (GSENM). Specifically, the objectives of this effort were to: 1) evaluate the spatial and temporal representativeness of legacy and contemporary GSENM vegetation assessment and monitoring data; 2) compare the sampling methodologies used to collect these data; and 3) evaluate the compatibility and potential for integration of these data for analysis purposes and to inform decision-making on the monument.

Legacy datasets at GSENM go back several decades (to at least the 1980s, and in some cases even further) and contain important baseline information about the monument in the context of ongoing and future landscape change. These data were collected largely to support evaluation of rangeland health and land use management (i.e., grazing). BLM uses four indicators or standards to evaluate rangeland health: 1) soils and their ability to sustain productivity and reduce erosion; 2) hydrologic function; 3) biotic integrity (desired species and species at risk); and 4) water quality.

All data were collected by GSENM with the goal of evaluating one of these four rangeland health standards. Accordingly, the legacy data evaluated in this effort consisted of rangeland health ('upland') and riparian ('lentic' and 'lotic') datasets. Numerous other historical datasets existed, but either did not exist in electronic-file form or were of limited utility.

Datasets considered to be of limited utility were typically incomplete with only a small portion of the sites entered into a database or they lacked critical attribute data. For example, the 'range improvement' samples consist of location data on corrals, troughs, improved springs, dams, and trend sites. The focus for this analysis was on vegetation monitoring data and, as such, only the trend data was relevant. This dataset, however, is currently missing over 100 samples and a majority of its attribute data. Thus, we did not include trend data in this analysis.

Contemporary data included Assessment Inventory and Monitoring (AIM) data. The overarching goal of the AIM strategy is similar to the goals for previous data collection efforts, but with a focus on statistical validity (e.g., based on probabilistic sampling) and the need to make inference at multiple scales (e.g., the ability to aggregate information from individual field offices up to a district or even a region). Since there were differences in the design and implementation of the AIM data after the first year, we have separated these data into two separate categories: 2013 AIM data (a focus of this report) and all other AIM data (i.e., data collected from 2014 - 2018).

Ecological and administrative subdivisions of the landscape

The project area was defined in reference to a Bureau of Land Management (BLM) planning area, which includes 1.9-million acres within the monument and an additional 0.4-million acres extending past the GSENM boundaries (Figure 1). The majority of data collection efforts at GSENM have been conducted throughout the entire 2.3 million-acre planning area.

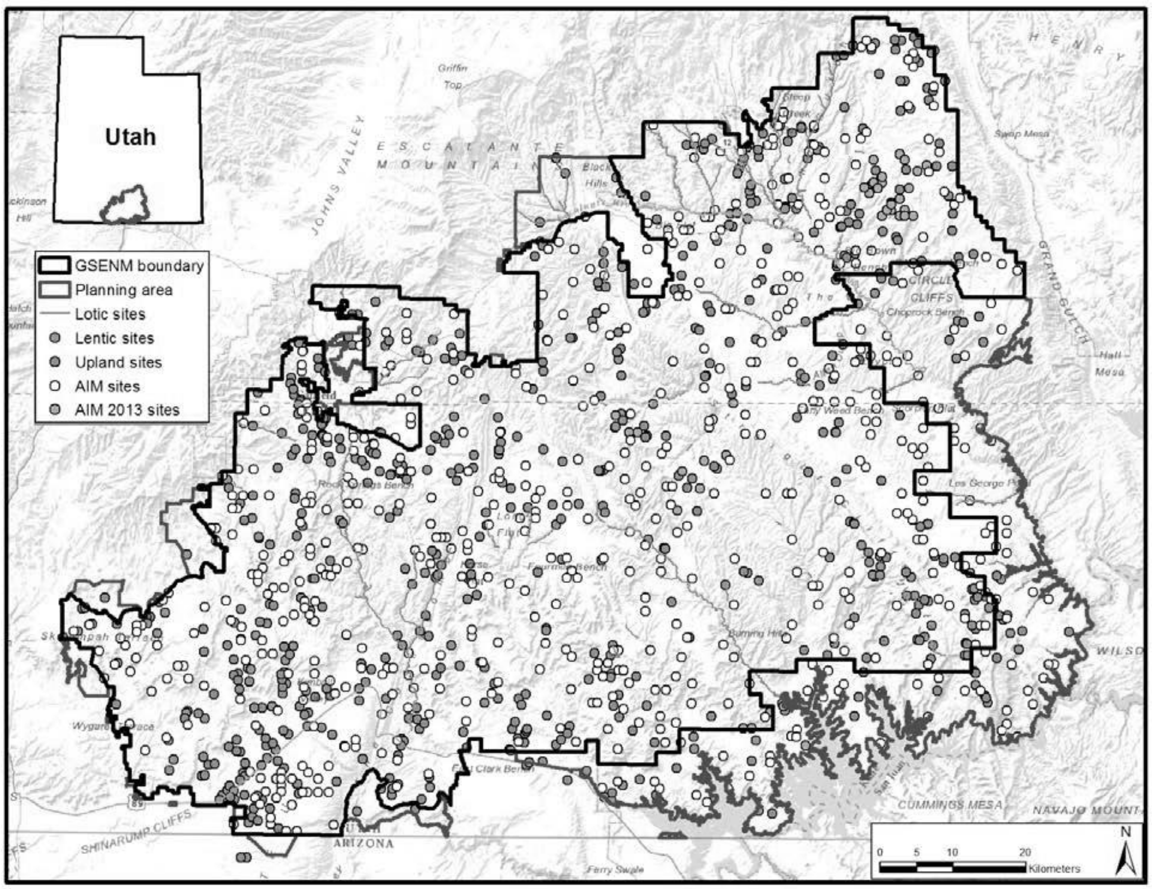

Figure 1. Map of the GSENM boundary and planning area with locations of some of the vegetation and monitoring sites.

There are several different scales/subdivisions of land occurring within the GSENM boundary and all can play a role in how data is analyzed and summarized based on management objectives or research questions. Some of these include allotments, pastures, watersheds, soil map units, and ecological sites. Within the monument boundary, land is subdivided into 81 grazing allotments and these allotments are typically divided into two or more fenced pastures (*n* = 338) to facilitate livestock management. Pastures represent the smallest management

units in the monument and can range in size from approximately 12,400 to 134,000 acres (5,000 ha to 54,288 ha; (Miller 2008). Pastures are typically nested within allotments, but occasionally pastures extend beyond allotment boundaries and outside the monument boundary (Figure 2).

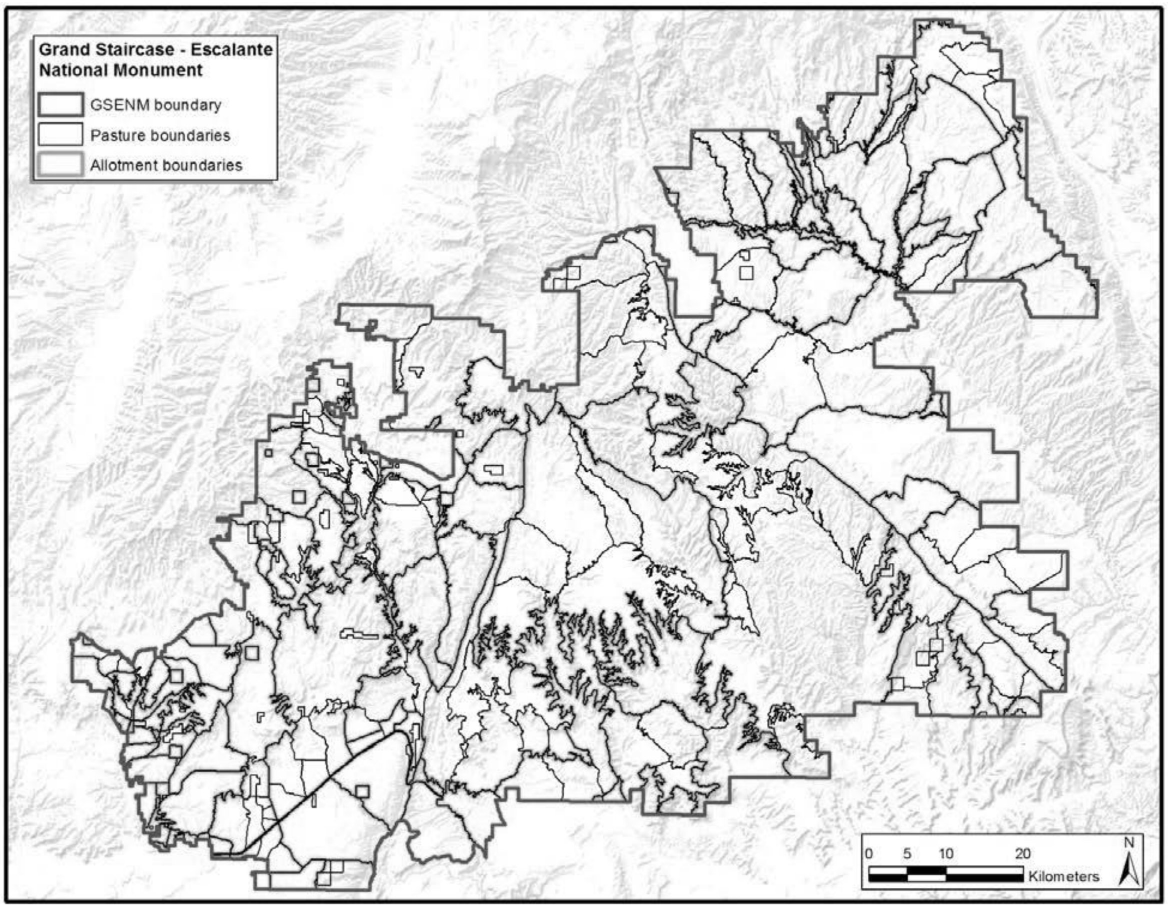

Figure 2. Scales/subdivisions of land occurring within the GSENM boundary. While allotments (in yellow) and pastures (in black) generally have a one:many relationship, sometimes pastures and allotments are identical (one:one).

There are a few land areas within the monument boundary that do not fall into designated allotments. Some of these areas, however, do have pasture names associated with them, while others do not. Some of the samples (records in the lentic, lotic, and upland datasets) were given allotment names that do not match the name indicated for the sample in the original allotment data layer. Due to these inconsistencies we intersected sample locations for all datasets (lentic, lotic, upland, and AIM data) with the original allotment data layer to create a single, consistent allotment name for each sample. For sites that did not fall into a

designated allotment, the site received the pasture name or was noted as 'unalloted.' We used this information to summarize data by allotment.

Soils data (in large part because of the relationship with ecological sites) is an important stratifier in the context of the AIM data, and likely necessary in any attempt to integrate legacy and contemporary datasets. However, due to the lack of soils data in some regions of the planning area, and the lack of congruence of soils data from inside the GSENM boundary and the plan areas (Figure 2), we focused our analysis on areas within the monument boundary. This included 86% of plots sampled across rangeland health, riparian, and AIM data collection efforts (Table 1).

Table 1: Representativeness, including temporal coverage and counts of the number of samples, of legacy and contemporary datasets. Legacy datasets (for the purpose of this study) consisted of rangeland health ('upland') and riparian ('lentic' and 'lotic') data, while contemporary datasets consisted of the Assessment Inventory and Monitoring (AIM) data.

Dataset	Years collected	# sites within GSENM boundary	# sites outside GSENM boundary	Total sites
Lentic	2000, 2001, 2002, 2004, 2005, 2007*	118	26	144
Lotic	1997, 2001-2003	291	64	355
Upland	2002-2003*	470	49	519
AIM 2013	2013	32	3	35
AIM (2014 - 2018)	2014-2018	507	81	588

*The majority of sites do not have dates associated with them.

Dataset descriptions and data collection methodologies

Lentic and lotic data

Both lentic (standing water systems) and lotic (running water/riverine systems) data were collected using a Proper Functioning Condition (PFC) assessment (Prichard 1998, 1999). This is a qualitative method for assessing the condition of riparian wetland areas and is based on both abiotic and biotic factors as they relate to physical condition. The data collected consisted of a checklist with *yes* or *no* answers; however, occasionally items on the checklist had to be quantified to determine how they should be answered. The capability and potential of natural riparian-wetland areas are characterized by the interaction of hydrology, vegetation, and erosion/deposition (soils) attributes and processes.

The assessment of these areas consists of a checklist and rating system used to determine four different condition categories: proper functioning condition (or PFC), functional-at-risk, nonfunctional, and unknown. A riparian-wetland area is considered in PFC when adequate vegetation, landform, or large woody debris is present and 1) dissipates energies associated with wind action, wave action, and overland flow from adjacent sites; 2) filters sediments and aids floodplain development; 3) improves flood-water retention and groundwater recharge; 4) develops root masses that stabilize islands and shoreline features against cutting action; and 5) restricts water percolation. A functional-at-risk riparian wetland area will possess some or even most of the elements listed above, but has at least one attribute that gives it a high probability of degradation with wind action, wave action, and overland flow events. If a riparian-wetland site is determined to be functional-at-risk, then trend must be determined to see if it is moving towards or away from PFC. Sites must be revisited on a scheduled basis in order to reflect trends. A nonfunctional riparian-wetland area clearly lacks the elements listed in the above PFC definition. An unknown site lacks specific information for the area and therefore cannot be evaluated.

Stratification methodology

Both the lentic and lotic sites were not systematically or probabilistically selected across the monument. Instead all known lotic and lentic locations where PFC assessments were conducted in the past were chosen.

Upland data

Upland data were collected using the Interpreting Indicators of Rangeland Health technique (Pellant et al. 2000). This technique uses qualitative assessments to identify the status of rangeland health by assessing three rangeland health attributes: soil/site stability, hydrologic function, and integrity of the biotic community. Different combinations of 18 qualitative indicators were used to determine the status of each of the three attributes (Table 2). Indicators and attributes for a particular assessment area were evaluated and rated according to the degree to which they depart from benchmark or reference conditions described in ecological site descriptions prepared by the Natural Resources Conservation Service (NRCS) or in ecological reference areas (Pellant et al. 2000). An ordinal, five-class rating system is used with degree of departure rated as none to slight (NS), slight to moderate (SM), moderate (M), moderate to extreme (ME), or extreme (E). To help determine indicator departure from an ecological site description (ESD) quantitative data was collected on percent cover of life forms (i.e., grasses, forbs, shrubs, trees, succulents, and biological crusts) and ground cover (i.e., vascular plants, standing dead vegetation, litter, biological crust, rock/gravel, and bare ground), species dominance and composition, and functional/structural groups. Data on ground cover and plant community composition were collected following the step-point technique

(Coulloudon et al. 1999).

Table 2. Brief description of 18 rangeland health indicators and their applicability to the three rangeland health attributes (adapted from Miller 2008).

Indicator and brief description	Soil site stability	Hydrologic function	Biotic integrity
1. Rills – frequency and spatial distribution of linear erosional rivulets	Yes	Yes	No
2. Water flow patterns – amount and distribution of overland flow paths that are identified by litter distribution and visual evidence of soil and gravel movement	Yes	Yes	No
3. Pedestals and/or terracettes – frequency and distribution of rocks or plants where soil has been eroded from their base (pedestals), and/or occurrences of erosional terracettes	Yes	Yes	No
4. Bare ground – size and connectivity among areas of soil not protected by vegetation, biological soil crusts, litter, standing dead vegetation, gravel or rocks	Yes	Yes	No
5. Gullies – amount of channels cut into the soil and the amount and distribution of vegetation in the channel	Yes	Yes	No
6. Wind-scoured areas, blowouts, and/or deposition areas – frequency of areas where soil is removed from under physical or biological soil crust or around vegetation or frequency of accumulation areas of soil associated with large structural objects, often woody plants	Yes	No	No
7. Litter movement – frequency and size of litter displaced by wind and overland flow of water	No	Yes	No
8. Soil surface resistance to erosion – ability of soils to resist erosion through the incorporation of organic material into soil aggregates	Yes	Yes	Yes
9. Soil surface loss or degradation – frequency and size of areas missing all or portions of the upper soil horizons that normally contain the majority of organic material at the site	Yes	Yes	Yes
10. Plant community composition and distribution relative to infiltration and runoff – the community composition or distribution of species that restrict infiltration of water on the site	No	Yes	No

11. Compaction layer – thickness and distribution of the structure of the soil near the soil surface	Yes	Yes	Yes
12. Functional/structural groups – the # of groups, the # of species within groups, or the rank of order of dominance groups	No	No	Yes
13. Plant mortality/decadence – frequency of dead or dying plants	No	No	Yes
14. Litter amount – deviation in the amount of litter	No	Yes	Yes
15. Annual aboveground production – amount relative to the potential for that year based upon recent climatic conditions	No	No	Yes
16. Invasive plants – abundance and distribution of invasive plants regardless if they are noxious weeds, exotic species, or native plants whose dominance greatly exceeds that expected for the ecological site	No	No	Yes
17. Reproductive capability of perennial plants – evidence of the inflorescences or of vegetative tiller production relative to the potential for that year based upon recent climatic conditions	No	No	Yes
18. Biological soil crusts – amount, spatial distribution, and degree of development	Yes	Yes	Yes

Stratification methodology

Since ecosystem conditions vary among different soil and ecological sites due to management activities such as grazing and climate variability, digital spatial data delineating soils and ecological sites were used to stratify each pasture into soil based assessment units. Within these sampling units, upland sampling sites were identified using opportunistic sampling rather than probabilistically. For each pasture, soil map units were ranked in descending order according to their total area in the pasture, and at least one assessment was conducted in the predominant ecological site in the soil map units that accumulatively accounted for 75% of the pasture area. Assessments also were conducted in areas expected to receive relatively high livestock use even where these areas were associated with minor soil components or soil map units that fell below the 75% cut-off in a particular pasture.

AIM data

In 2013, the BLM at GSENM implemented a pilot survey following the AIM strategy (Toevs et al. 2011). The AIM strategy uses six core indicators to assess the three rangeland health attributes described above: bare ground, vegetation composition, non-native invasive plant species, plant

species of management concern, vegetation height, and proportion of large intercanopy gaps. These six indicators are collected using quantitative land cover and vegetation data including percent cover forbs, grasses, shrubs, trees, succulents, bare ground, non-native invasive species, and plant species of management concern. Three main standardized measurement methods were used to gain information on the six indicators: line-point intercept with plot-level species inventory, vegetation height, and canopy gap intercept (Table 3). In addition to data being collected on the six indicators, site characteristics that are unlikely to change between visits were recorded. These typically included information on location, elevation, slope, aspect, topography, soil horizons and soil profiles. Similar to upland data, AIM data will be referenced to departure from reference conditions; however, the process for this classification has not yet been determined.

Table 3. Brief description of six core health indicators and their applicability to the three rangeland health attributes (adapted from MacKinnon et al. 2011).

Indicator and brief description	Collection method
1. Amount of bare ground (%) – used as an indicator of erosion potential, forage production, wildlife habitat, and risk of invasion by non-native plants	Line-point intercept method
2. Vegetation composition – collected as % perennial forbs, annual forbs, perennial grass, annual grass, succulent, shrub, tree, sub-shrub, sagebrush	Line-point intercept method supplemented with plot-level species inventory
3. Non-native invasive plant species – collected as % and # of non-native invasive plant species. These species have the ability to significantly alter resource use sustainability, site resilience, disturbance regimes, or ecohydrology.	Line-point intercept method supplemented with plot-level species inventory
4. Plant species of management concern – collected as presence and percent cover. These species can be sensitive to site disturbance, provide important ecosystem functions, or contribute to biological diversity.	Line-point intercept method supplemented with plot-level species inventory
5. Vegetation height – used to characterize wildlife habitat and estimate wind erosion potential	Height at selected line-point intercept points
6. Proportion of soil surface in large intercanopy gaps – used to estimate erosion potential	Canopy gap intercept

Stratification methodology

The stratification design for the AIM data changed after the first year of implementation. During the first year (2013), the AIM sites were stratified by the dominant soil series within a

map unit (i.e., ecological site). The soils data originated from the soil survey data published by the Natural Resources Conservation Service (Sutcliffe 2007). The soils data consists of map units representing areas dominated by one or more major types of soil. For each map unit, the three dominant soil components and their percentages were recorded. In order to condense this dataset, BLM used only the dominant soil type within each map unit to stratify the AIM data. Approximately three sites were selected in each of the ecological sites within an allotment. This stratification design allowed the data to be aggregated by allotment. For each year, sites were selected within a limited number of allotments. Thus, for each year data was collected, all sites were concentrated in one section of the monument instead of being spread across the entire monument. For example, in 2013, a total of 32 sites were sampled across only two allotments (Last Chance and Death Hollow) (Figure 3). Within the Death Hollow allotment, 21 sites were distributed across five dominant soil series: semidesert loam, rock outcrop, semidesert shallow clay, semidesert shallow loam, and semidesert shallow shale. In the Last Chance allotment, 11 sites were distributed across six dominant soil series: semidesert loam, rock outcrop, desert stony loam, upland loam, upland shallow loam, and desert shallow clay. Since environmental factors, such as precipitation, can change significantly from year to year, sampling only a small proportion of the monument each year might limit the inferences you can make at a larger geographic and temporal scale.

After 2013, the stratification methodology and scale was changed for all future years of AIM data collection, including based on ESDs for 2014-2015. The new design involved selecting sites across the entire monument each year instead of within just a few allotments. For example, in 2014 a total of 78 sites were sampled across 36 allotments. The BLM wanted to use continuous physical factors (precipitation, elevation, slope, and aspect) along with soil type to determine site selection since all of these factors together drive vegetation. Sites were stratified by precipitation and vegetation and weighted by area and production. This new design allowed more sites to be placed in areas with higher productivity. Overall 500 samples were spread across the entire monument and will be sampled over the course of five years (2014-2018).

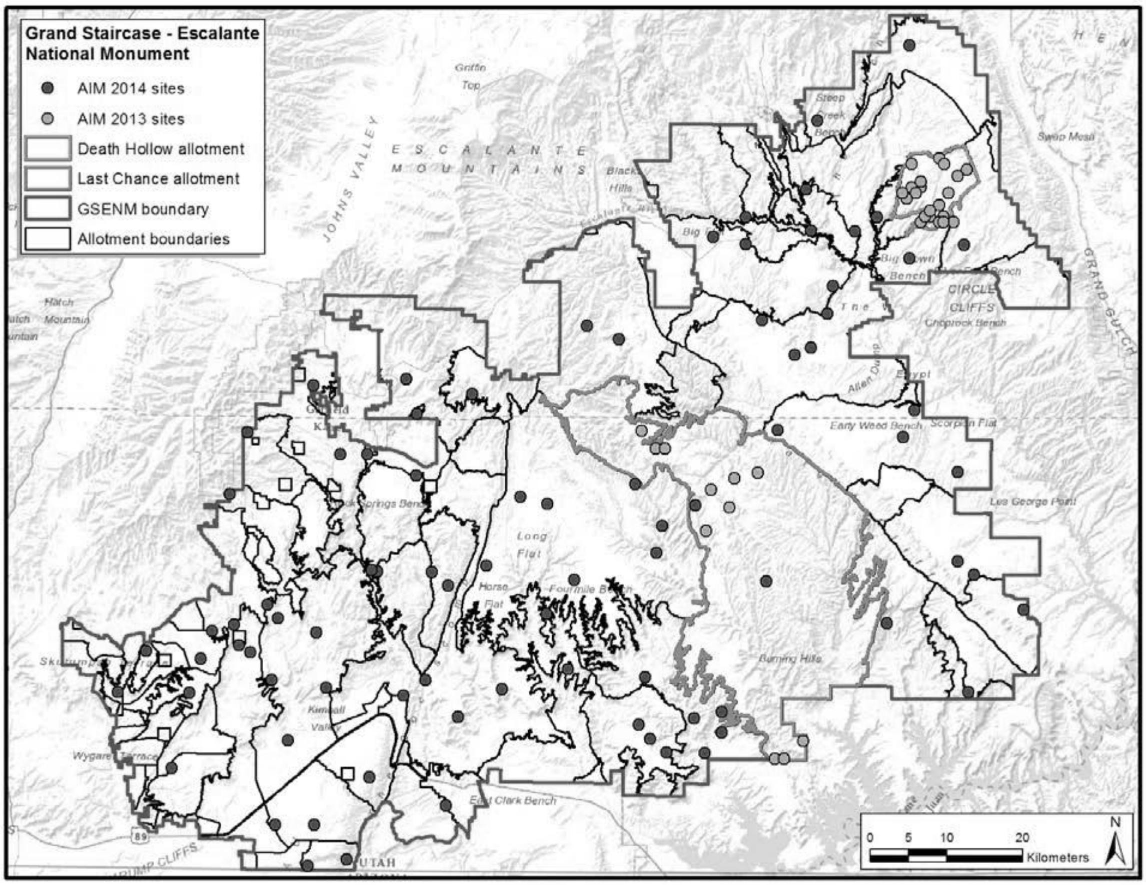

Figure 3. Map illustrating the differences between the 2013 AIM data stratification design and the new AIM data design. The Death Hollow and Last Chance allotments are highlighted to better depict the placement of the 2013 AIM sites.

Representativeness of the data

The representativeness of data is a basic statistical concept, often defined in relation to a sample's ability to accurately represent a population of interest. In the context of data collection efforts at GSENM, the population of interest typically entails biological communities. If samples are selected, e.g., as a matter of convenience, or if certain elements of the landscape are undersampled, bias can occur, which can create problems with drawing inference from the data. Unfortunately, unlike more recent data collection efforts, most legacy data on the monument were not generated according to a probabilistic sampling design. While it can be difficult, if not impossible, to assess the representativeness of a given sample, we make an

effort to do so by evaluating the spatial distribution and number of samples against both management units (allotments) and biotic communities (using proxies such as soil units, NLCD).

The new AIM data sites (2014-2018) were spatially spread out the most across the monument, with sites occurring in 72 allotments (Figure 3). The upland data was the next most extensive dataset with sites occurring in 68 allotments. Lentic sites occurred in only 36 allotments and lotic sites occurred in 46 allotments. The 2013 AIM data occurred in only two allotments: Last Chance and Death Hollow. There are a few allotments (n = 9) within GSENM that currently have no legacy or contemporary data sites. These mostly occurred in the southwest section of the monument. Some of the larger allotments with no data include Johnson Point, Boot, Hells Bellows, Neaf, and White Sage allotments.

Several areas in the monument have different management and disturbance histories, including seeding, fire, or grazing. From a management perspective, these areas are of great interest to BLM managers. Seeding areas are areas that have been seeded with native grass and forb seed to improve vegetation for livestock and wildlife use. Data collected at legacy and contemporary sites can be used to determine whether these management strategies are having an impact on the health of the ecosystem. For the majority of datasets, only a few sites fell within seeding areas or fire boundaries (Figure 4, Table 4). Unfortunately much of the legacy data is currently missing dates within the database, so it is difficult to tell whether the data was collected before or after seeding or fires occurred. Once these dates are uploaded into the database then vegetation and riparian data can be summarized in these management areas.

Finally, representativeness of data was evaluated using statistics related to the number of samples in different administrative or ecological units i.e., allotments and ecological sites (Figures 5 and 6, respectively). We also used the known proportion of National Land Cover Database (NLCD) cover classes within the administrative boundary of GSENM (Figure 7) to evaluate the extent to which samples from contemporary and legacy datasets capture each class (Figure 8).

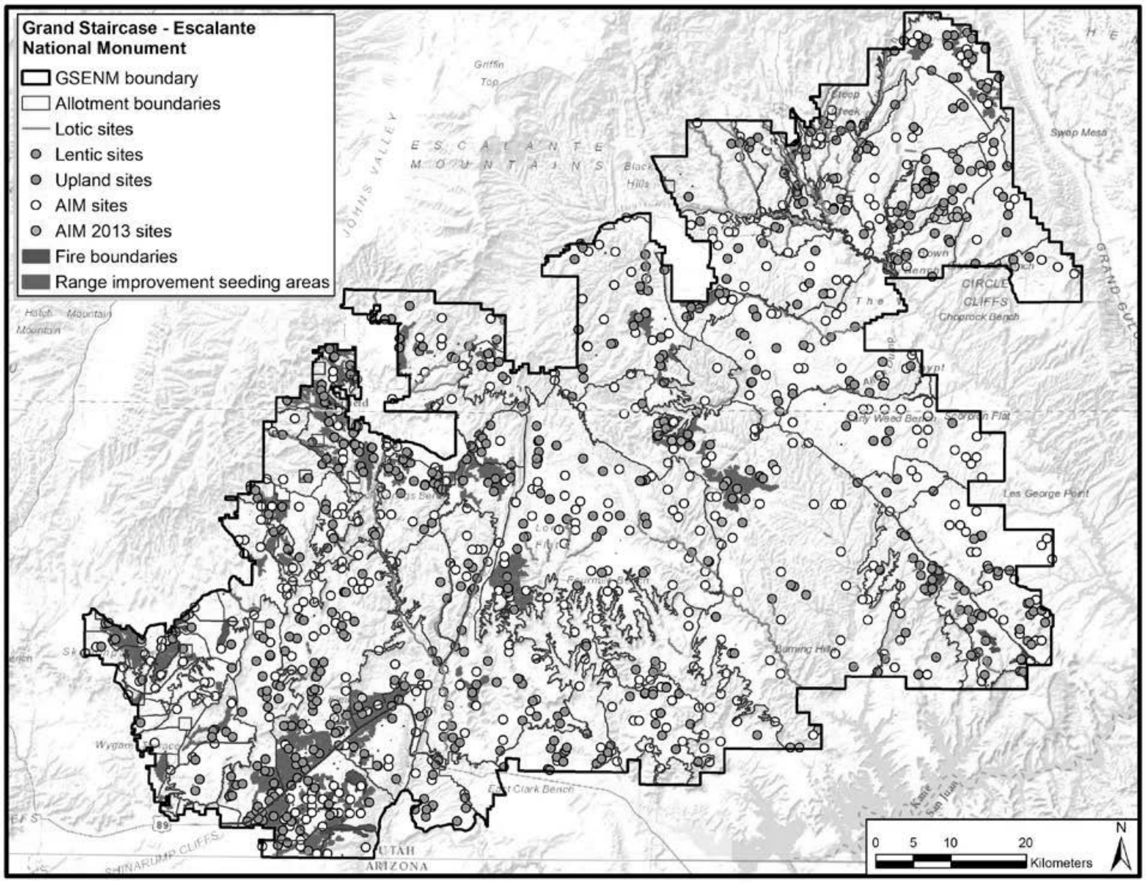

Figure 4. Spatial distribution of legacy and contemporary samples within GSENM. Also shown are fire boundaries and range improvement seeding areas within the monument.

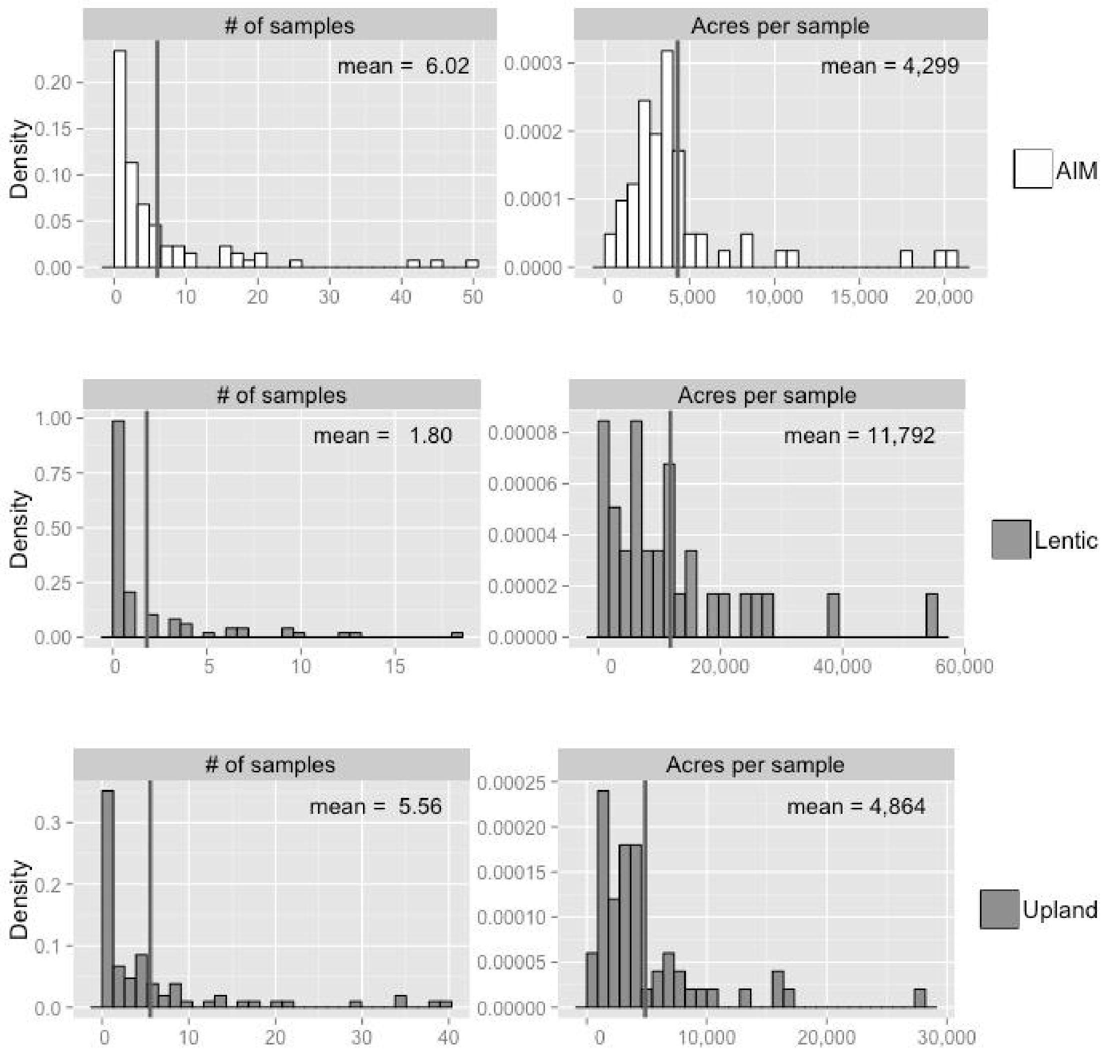

Figure 5: The distribution of the number of samples (left column) and acres per sample (the number of samples per unit area; right column) in allotments for both contemporary (AIM 2014-2018) and legacy datasets (Lentic and Upland). Means are indicated by the vertical red lines and values in the upper right corner of each panel.

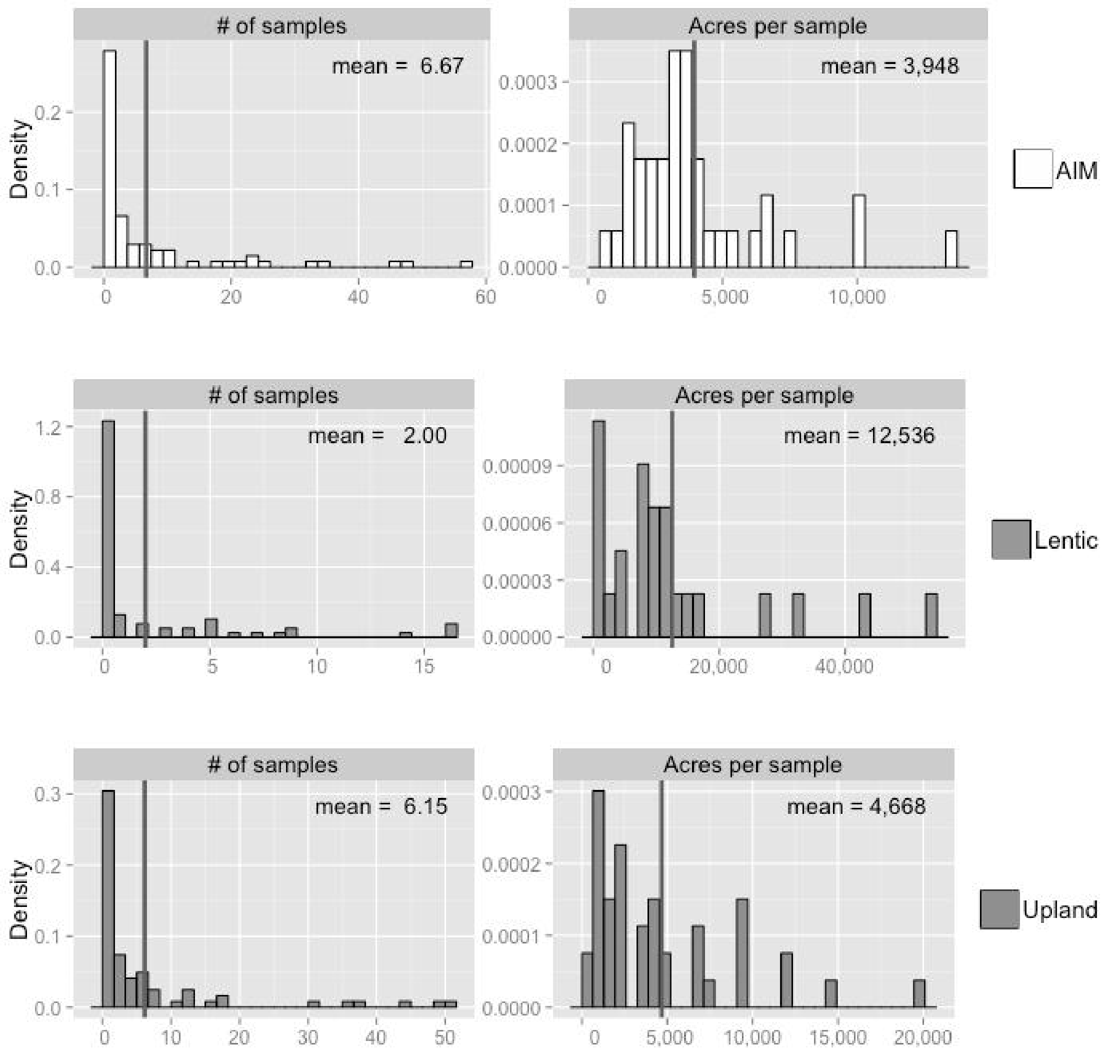

Figure 6: The distribution of the number of samples (left column) and acres per sample (the number of samples per unit area; right column) in ecological sites for both contemporary (AIM 2014-2018) and legacy datasets (Lentic and Upland). Means are indicated by the vertical red lines and values in the upper right corner of each panel.

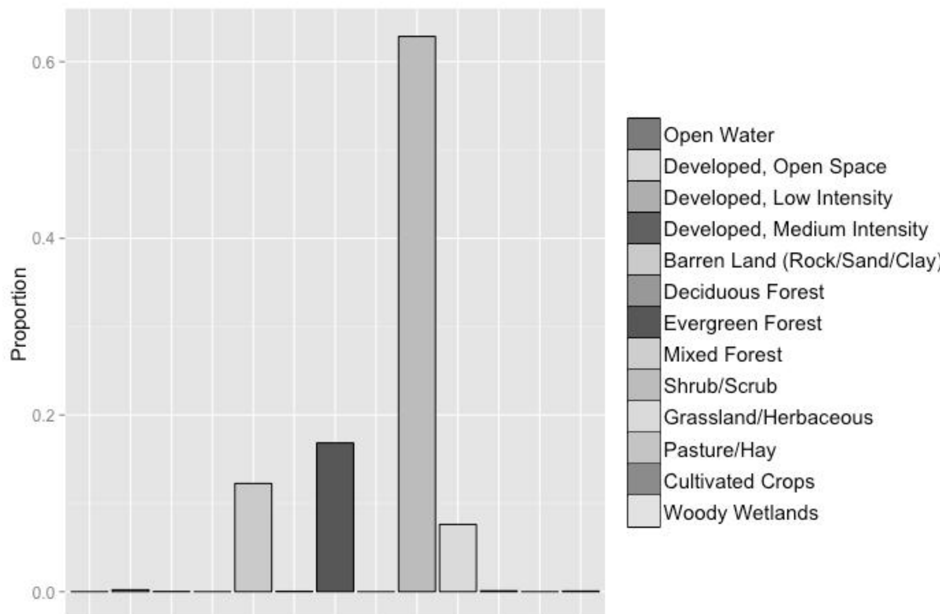

Figure 7: NLCD (2006) class proportions within the boundary of GSENM.

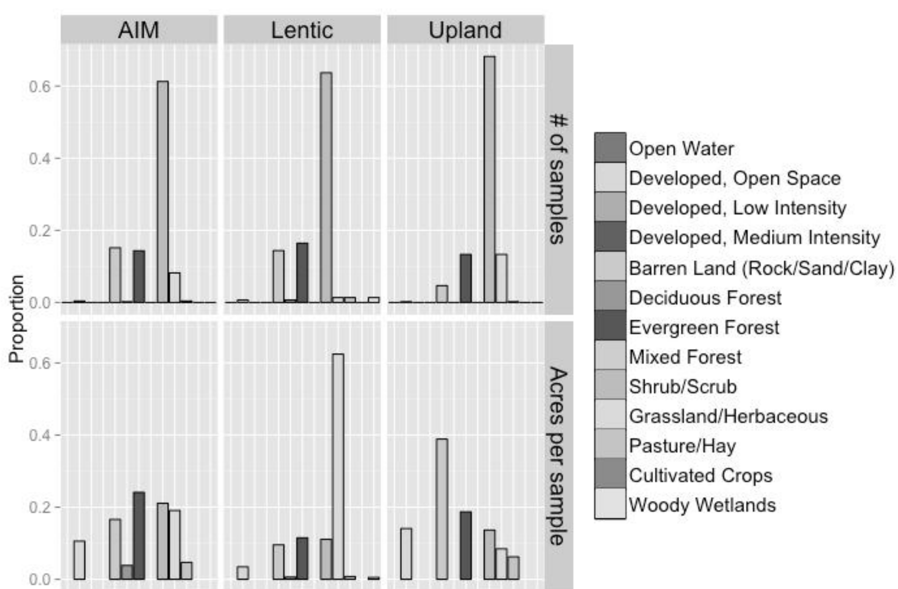

Figure 8: The number of samples (top row) and acres per sample (the number of samples per unit area; bottom row) in each NLCD (2006) class for both contemporary (AIM 2014-2018) and legacy datasets (Lentic and Upland).

Table 4: Distribution of samples in land areas that experienced seeding and wildfires. Note that additional information regarding the timing of seeding or wildfires will need to be joined to each sample/sampling event in order to make meaningful inferences regarding the effects of these management activities and disturbance events.

Dataset	# sites within seeding areas	# sites within wildfire boundaries	# sites in ungrazed allotments
Lentic sites	9	2	7
Lotic sites	9	0	16
Upland sites	86	5	34
AIM 2013 sites	5	0	0
AIM sites	28	1	27

Data summary

Lentic and lotic data

About half of the lentic sites were classified within one of the functional at risk categories and a third of the sites were considered to be in PFC. Only 15% of the sites were considered non functioning (Table 5). The majority of lotic sites were classified as PFC while about a third were considered functional-at-risk with a downward trend or non functioning. There were a total of 94 lentic and lotic sites that were originally classified as Functional at Risk and only 16 of these were revisited. It is important to continue to monitor these sites to determine whether they are moving more towards PFC or non functioning.

By evaluating the data in a spatially explicit fashion, sites can be intersected with other spatial data layers including grazing activity, seeding areas, wildfires, soils data, and a wide variety of other spatial data to start looking at relationships between site characteristics and management and environmental data. Figure 4 illustrates this by showing the functioning condition of lentic and lotic sites overlaid on top of grazing activity, wildfire boundaries, and seeding areas. The northeast section of the monument near Willow Gulch allotment stands out has having a large cluster of lentic and lotic sites that are in PFC. This area of the monument has a few non active and reserve common allotments and also appears to have less grazing activity overall. In addition, there are no large wildfires or seeding areas. These other spatial data layers can help provide insight on why so many lentic and lotic sites are in PFC.

Table 5. Percentage of lentic and lotic sites that fell within each of the five condition categories for addressing functional conditions.

Condition category	Lentic sites	Lotic sites
Proper functioning condition	32%	44%
Functional at risk - upward trend	9%	13%
Functional at risk - downward trend	27.5%	14%
Functional at Risk - trend not apparent	15%	15%
Non-functioning	15.5%	14%
Unknown	1%	0%

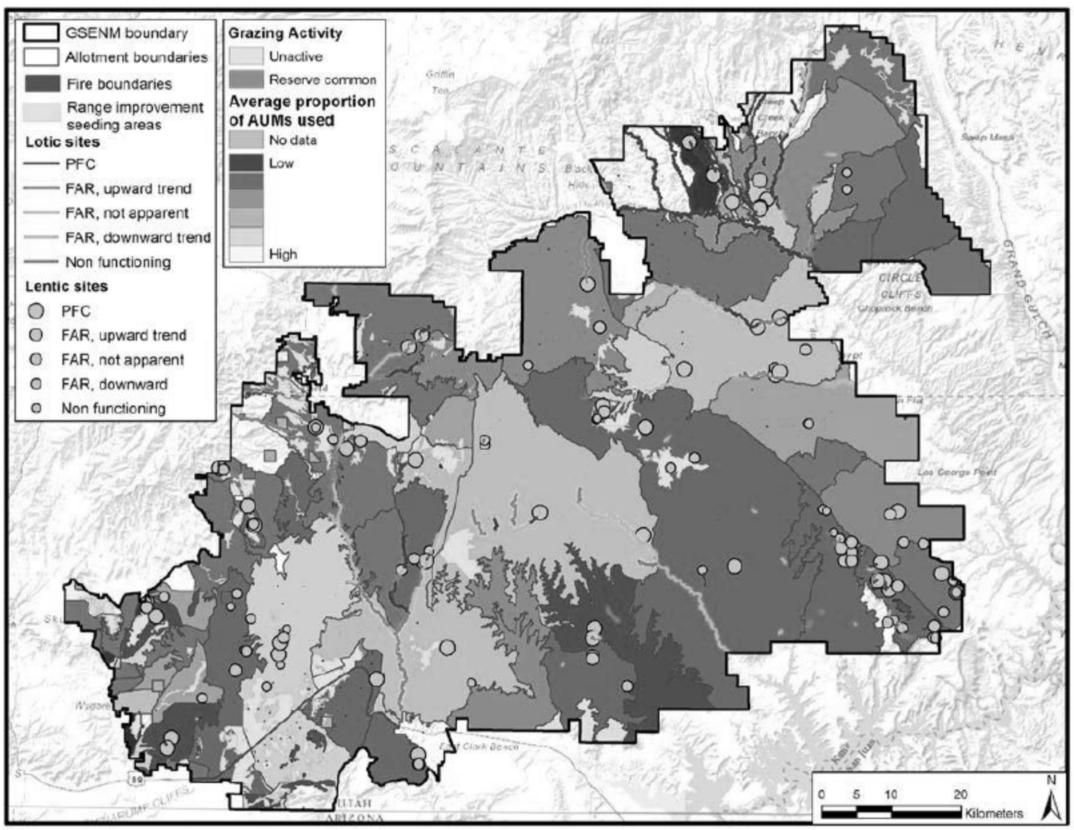

Figure 9. Map of lentic and lotic data illustrating functioning condition of riparian areas across different grazing activities and wildfire and seeding areas.

Upland data

The majority of upland sites had characteristics that placed them in the moderate to extreme departure from ecological condition category for all three of the rating categories (soil site stability, hydrologic function, and biotic integrity) (Table 6). When we look at the data spatially with grazing and management areas (Figure 10) patterns are not as clear as with the lentic and lotic data. Additional spatial data such as precipitation, temperature, or soils data could provide additional insight on trends.

Table 6. Percentage of sites that fall within each of the departure from ecological description rating categories for the upland dataset.

Departure from ecological description	Soil site stability	Hydrologic function	Biotic Integrity
None to slight	< 1%	< 1%	< 1%
Slight to moderate	6%	4.5%	5%
Moderate	24%	22.5%	27.5%
Moderate to extreme	47%	52%	52.5%
Extreme	22%	20.5%	14%

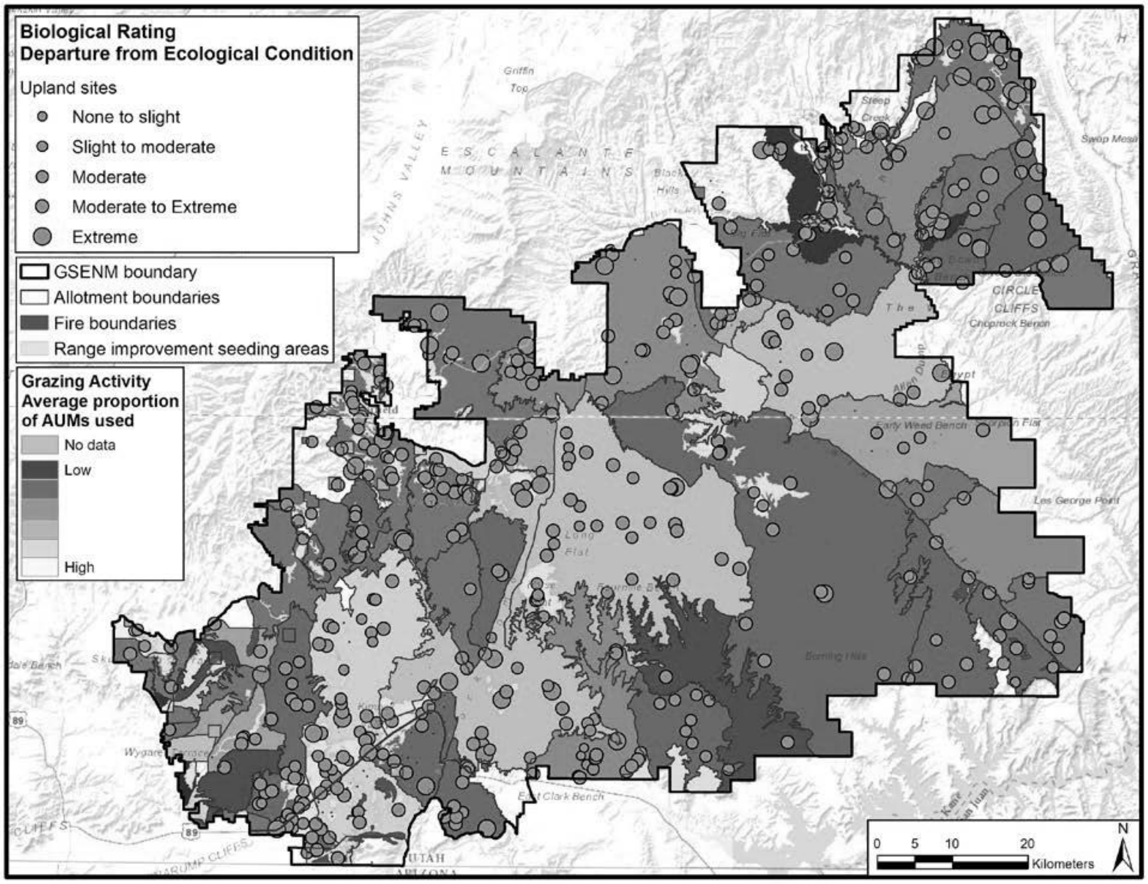

Figure 10. Map of upland data illustrating departure from biological condition for the biological rating category across different grazing activities and wildfire and seeding areas.

AIM data

Since we have quantitative data for the 2013 AIM sites, we can summarize the data by allotment, pasture, soil type, or ecological site. We provide an example below of summary information by allotment and ecological site (Table 7). AIM 2013 data has not been classified by departure from ecological condition yet, so at this time we are unable to summarize data in the same format as the upland data. The AIM data (2014 - 2018) is still being collected and we currently do not have any data to summarize.

Table 7. Example of how quantitative data can be summarized across allotments or ecological sites.

Allotment	# of sites	Average species richness	Average foliar cover (%)	Average Invasive species (%)	Average herbaceous height (cm)
Death Hollow	21	27	19.0	1.0	7.2
Last Chance	11	18	26.0	1.0	8.8
Ecological Site					
R035XY011UT	4	29	18.0	0.8	13.2
R035XY109UT	1	14	26.0	0	6.8
R035XY124UT	1	13	2.0	0	6.3
R035XY139UT	1	21	21.3	4.2	5.6
R035XY206UT	1	41	24.0	0	4.8
R035XY209UT	3	19	21.1	0	5.6
R035XY215UT	3	31	17.8	2.5	4.0
R035XY221UT	2	25	18.0	0	6.5
R035XY234UT	3	18	13.8	0	2.7
R035XY239UT	1	31	28.7	0	10.1
R035XY240UT	1	22	35.3	3.1	13.9
R035XY308UT	4	18	31.3	0	14.5
R035XY315UT	2	23	25.0	0	3.0
UNKNOWN	5	27	20.8	0	6.9

Comparison of sampling designs

The primary challenge associated with evaluating the compatibility and potential for integration of the legacy and AIM data entailed the non-probabilistic vs. probabilistic sampling designs used to collect the data (Table 8).

Table 8. Summary sampling design and temporal information for each of the five datasets collected on the GSENM monument.

Dataset	Sampling design	Data type	Dates collected
Lentic	non-probabilistic	qualitative	2000, 2001, 2002, 2004, 2005, 2007*
Lotic	non-probabilistic	qualitative	1997, 2001-2003
Upland	non-probabilistic	qualitative	2002 - 2003*
AIM 2013	probabilistic	quantitative	2013
AIM new	probabilistic	quantitative	2014-2019

*The majority of sites do not have dates associated with them.

Comparisons of lentic and lotic data to AIM and upland data

AIM data cannot be directly compared to lotic and lentic data due to differences in sampling design (non-probabilistic versus probabilistic), type of data collected (qualitative instead of quantitative), and overall differences in data (data collected to determine proper functioning condition of riparian areas versus departure from ecological site descriptions of uplands). Changes, however, at upland or AIM sites within the same watershed may influence the functionality of lotic or lentic sites since upland and riparian areas are interrelated and cannot be managed separately. Since upland, lentic, and lotic data were collected around the same time period, some of the upland data collected might provide insights to the functioning condition of lentic and lotic sites during that time period.

For example, the lentic site “Little Red Rock Spring” occurs in the Dry Fork Coyote Gulch watershed and was classified as functional at risk with a downward trend in 2002. Within this same watershed and allotment two upland sites occur (Figure 11). Both of these sites were also sampled in 2002 and occur in the same dominant soil series (semi-desert sand) as the lentic site. Both of the upland sites were classified as moderate departure from ESD for both the soil site stability and biotic integrity rating, while the hydrologic function rating was classified as moderate to extreme. The upland sites had severe rill formation and a high number of gullies indicative of higher disturbance and loss of vegetative cover. They also had high plant mortality, low annual production, and an extensive compaction layer. All of these factors indicate that greater erosion is occurring in these areas potentially due to disturbance. The disturbance and increased runoff at these upland sites are probably impacting the functionality of the Little Red Rock Spring site and further investigation at these upland sites might reveal why the lentic site is functional at risk with a downward trend. Potential changes at the upland sites to reduce

disturbance along with changes at the lentic site might be needed to switch it from a downward trend to an upward trend.

If additional lentic and lotic data is collected in the future and around the same time period as the AIM data, then the AIM data collected might provide valuable information about why some lentic or lotic sites are in proper functional condition or not.

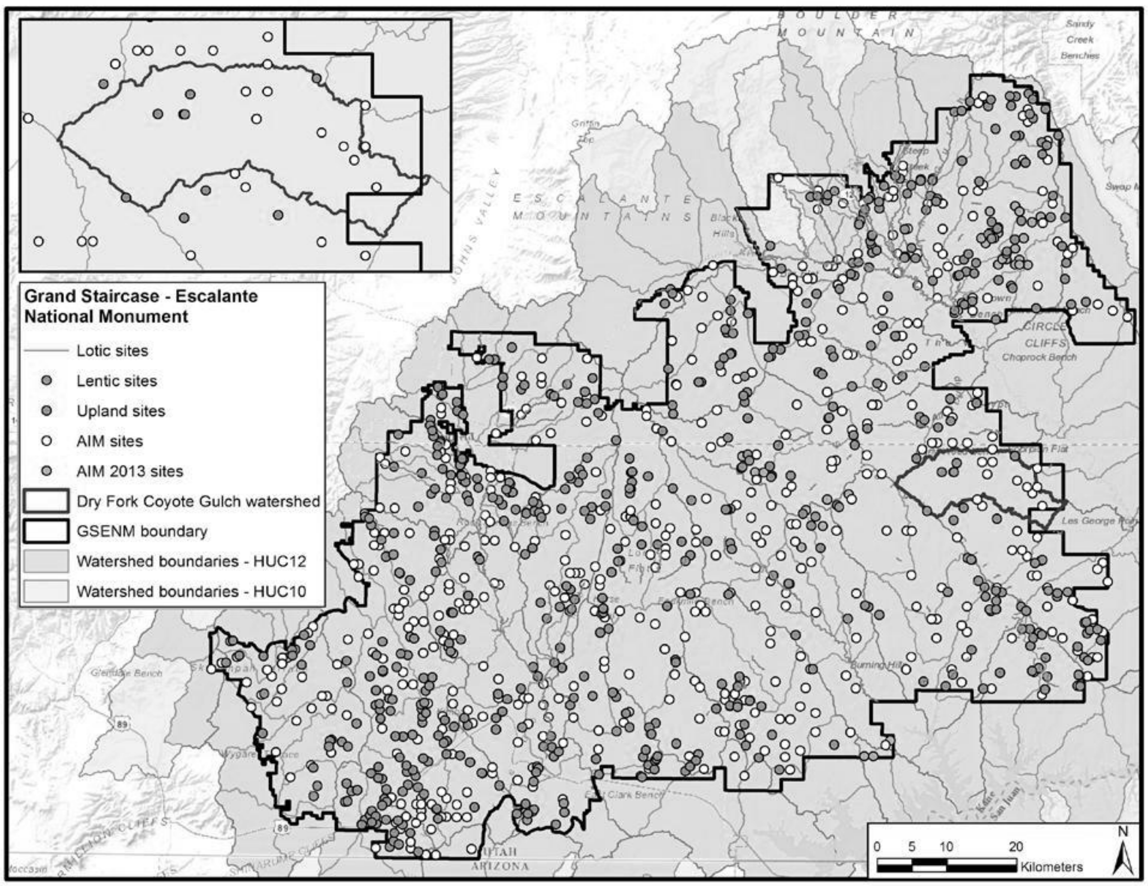

Figure 11. Map illustrating the relationship between upland and AIM sites to lentic and lotic sites within a watershed. Sites within the same watershed are interrelated and influence each other.

Comparison of upland and AIM data

The 17 indicators of rangeland health used in the upland dataset has a direct correspondence to the smaller subset of indicators used in AIM. Because of this, quantitative data collected at upland and AIM sites should be comparable among sites that meet matching criteria. Some of the comparable quantitative data includes percent cover of bare ground, perennial forbs, annual forbs, perennial grasses, annual grasses, succulents, shrubs, and trees along with

information on invasive species and plant species of management concern. By comparing these datasets, BLM managers should be able to get an idea on how similar areas could be changing through time and allow them to be able to detect trends.

Data regarding percent foliar cover or bare ground, however, should be compared cautiously when comparing upland sites to AIM sites. These were collected with two different sampling techniques: step point and line-point intercept. Although both of these methods can be used to monitor foliar cover and are collected in similar ways, they do have some differences. For example, with the line-point intercept method, cover is measured along a linear transect line and is based on the number of “hits” on a target species out of the total number of points measured along that line (Herrick et al. 2009). This technique allows for precise repeatable measurements. The step-point method, used with the upland data, is a similar method, but uses a transect bearing instead of an actual tape measure, making it more subjective and biased.

Data integration

GSENM staff worked iteratively with NAU staff to derive two ecologically meaningful matching schemes: 1) a ‘mukey’−based criteria (mukeys must match); and 2) an ‘ecoid’−based criteria. In the latter, ecoid4 must match if the percent cover of ecoid4 for the AIMs record is greater than or equal to 60%. In addition to sharing the same ecoid4, the percent cover of the ecoid4 match from the lentic or upland dataset must also be at least 60%. If ecopct4 is < 60% in any of the datasets, no matches will be identified. ecoid4 is simply ecoid1, and the percent cover of ecoid4 is the sum of the cover of that particular ecoid (for that record) (recall that in a number of cases, ecoid1 shows up in ecoid2 and ecoid3 columns). ecoid4 is just our attempt aggregate cover by common ecoid identifiers.

Both of the matching criteria referred to above have two additional requirements: 1) the elevation of a matching plot is within plus or minus 100 m of the AIMs record for which a match is being sought and 2) seeding areas are only paired with seeding areas, and non-seeding with non-seeding.

Comments on file: *match_key.csv*
Column 'fid_aims_p' are all the AIMs plot ids that are being matched to the upland and lentic datasets. The 'matching_rec_fid' are all of the id #s from either the upland or lentic datasets that match a particular AIM plot. The match type refers to whether we used the mukey-based criteria or the ecoid-based criteria for the analysis (more on this below). The dataset column lists the dataset that the match was in (upland or lentic). So, to take one match as an example, fid_aims_p == 0 matches fid_upland == 81 according to the mukey-based matching criteria.

Comments on file: *matches_by_criteria_and_stratum.pdf*

This file may have very limited utility. It is just a simple visualization of matches for different subsets of the AIM data (where each subset is tied to a particular stratum). If you toggle back and forth between different matching criteria within a given stratum, you can see how the spatial distribution and number of matches varies according to the matching criteria. To make sure you're able to do so (to toggle quickly between pages) open the pdf in Adobe Reader and then in the field menu go to View > Page Display > Single Page View. Per the legend, red points are always AIM plots, the yellow highlights behind red points indicate the set of AIM plots that are in a given stratum. Lentic and upland plots are green and blue, respectively. And matches between the yellow-highlighted AIMs plots and either lentic or upland plots are indicated by the pink 'halo' around lentic or upland points. The type of match is indicated parenthetically behind the stratum identified in the plot/page title. If it looks like there's a page missing (e.g., the ecoid-based matches for AIM plots in the sd_blackbru stratum, it just means there were no matches to plot, so the script moves on to the next stratum or criteria within a stratum to evaluate matches).

Comments on file: *matches_by_criteria_dataset_and_stratum.csv*
This is just one example of the sort of higher-level tabular summaries that can be generated from match_key.csv. Here you are looking at a summary of the count and proportion (the columns 'AimsRecsWithOneOrMoreMatch' and 'PropAimsRecsWithOneOrMoreMatch', respectively) of AIM records in a given stratum that have at least one match to records in the historical data (either upland or lentic, the 'dataset' column).

Needs and future directions

For the analyses and summaries described in this report, several potentially valuable datasets -- notably the trend and utilization data, and miscellaneous treatment success monitoring data -- were not taken into consideration. Additionally, the information required to bring the integrated data into an analysis phase has not yet been developed. We also recommend the following…

- Dates need to be added to all datasets;
- Quantitative raw data needs to be entered and joined to spatial data. The majority of the legacy data was collected as qualitative data, however, there was some quantitative data that was originally measured to derive these qualitative classifications. The inclusion of the quantitative data will allow for better data integration and comparisons across legacy and contemporary data sets;
- Complete data entry for the other legacy data sets, such as the range improvement trend data;

- Explore a new process for compiling legacy data in a geodatabase format, including the entry/digitization of primary data (e.g., as .csv tables) that can be ingested into Access, Excel, GDB, or other usable formats;
- Explore ways to use/analyze data so as to more efficiently and consistently inform future management decisions and reporting, support NEPA and proposals, address permit renewals, inform 'Assessment Reports,' etc. Consider streamlining associated analyses and inferences drawn, based on more accessible applications, including Excel or the R statistical programming environment;
- Consider implementing monitoring activities where archeological clearance for AIM was done at same time as AIM monitoring. When possible, attempt to co-locate monitoring efforts (e.g., trend, AIM, climate stations, etc.) so as to gain efficiencies in measurement and access logistics;
- Establish whether AIM can replace other forms of monitoring, or integrate these efforts to minimize redundancies in data collection;
- Because indicators are measured at different spatial scales, there is a need to map metrics (and therefore land health standards) to a consistent measurement unit;
- Derive additional spatial data on natural drivers (precipitation, temperature) and anthropogenic drivers (grazing, seeding, etc.). This will help managers determine the degree to which natural vs anthropogenic factors are driving trends in data.

Future directions for work include: 1) integrating some of the 'missing' legacy datasets with the historical data described in this report; and 2) remote sensing, spatial, and statistical analyses to bring the integrated data into an analysis phase to support decision-making activities around, for example, changes in plant community composition and production. The latter would allow key research questions to be addressed, for example, can the integrated data be used to determine the relative influence of natural environmental change vs. land-use practices in driving changes in plant community composition?

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